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An imaging software project Astro Space Locator (ASL for Windows):

New methods and software abilities

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Abstract. The ASL software is oriented towards the processing of the post-correlation data of VLBI and Space VLBI. ASL can be intended for image processing of data obtained from any modern VLBI instrument including future SVLBI project "Radioastron" or a project "Low Frequency VLBI Network (LFVN)" developed at the Astro Space Center. A current version of Astro Space Locator software contains the advanced procedures of Fringe-Fitting and `Self-Calibration`.

1. Introduction

The software project `Astro Space Locator for Windows 9x/NT/2000` is being developed by the Laboratory for Mathematical Methods of the ASC (`http://www.asc.rssi.ru`) to provide a free software package for VLBI data processing. We used Microsoft Windows 2000 and MS Visual C++ 6.0 on IBM compatible PCs as the platform from which to perform data processing and reconstruction of VLBI images. We believe this will make our software more easily available to a large number of astronomers who have access to PCs and notebooks. Our experience tells us that even though MS-Windows is considerably easy to use, it is not sufficiently robust, and it lacks some essential features for a more flexible implementation of computation-intensive algorithms.

2. Why ASL ?

There are many serious reasons, why ASL is not worth developing. Some of these reasons are :

- At present, a number of dependable software packages (Caltech, AIPS, Difmap) deal with the problem of data and image processing in radio astronomy; they are written for powerful computers; astronomers are accustomed to trust the results they obtain
- Usually, only the most up-to-date, state-of-the-art methods yield new results in radio astronomy. Such methods (e.g., spectral VLBI or especially future Space VLBI missions) require the most powerful computers which not all radio astronomy institutions can afford. The development cycle for advanced data processing methods is usually even more resource-hungry than the use of the final product; in particular, a large disk space is required
- Modern networking technology often compensates for the difference between a "personal" computer and a workstation, since the computing power of large computers becomes available at everyone's desk. Hence, the local computing resources of a personal computer can be used for tasks other than computation-intensive radio astronomy imaging problems, namely, for graphics output, publication preparation, networking support etc.
- Real-time processing and remote control of observation hardware is even more problematic in Russia.

On the other hand, there are at least five reasons, why ASL is well worth developing. These reasons are :

- The aim of developing ASL is to offer radio astronomers a tool to conduct efficient research on affordable computing hardware.
- To date, Russian astronomers in general are not experienced in the methods used for reconstructing images in radio astronomy. Yet active research in radio astronomy in Russia, as well as considerable scientific interest in the problems of image synthesis, call for such experience to be acquired. It is reasonable, therefore, to carry out local work on the subject.
- Previous software implementations have sometimes been sub-optimum in issues related to the efficiency of algorithms and programming technology. Adherence to UNIX/Linux is proclaimed. We will attempt to follow the most flexible approach - to use other operating systems, to realize distributed processing in an inhomogeneous network of small computers, etc
- With our software we hope to produce accuracy, novelty, and efficiency in the methods used
- The professional level of our programmers will permit us to solve the problem at hand. The end user, end programmer, and system programmer - all should feel the ease of use and accessibility of ASL

3. General description of ASL

`ASL for Windows` is based on the integrated environment paradigm. The source files used are in a special internal format, conventionally called UVX-format. A fairly general converter from UV-FITS format transforms visibility data values, as well as various accompanying information, into UVX-format. The FITS-reader permits visualisation of history records, extension tables, select sources, IFs, frequencies and polarizations to be included in the UVX-file. The current version of `Astro Space Locator` software consists of 3 integrated parts :

- `ASL Editor`
- `ASL Calibrator`
- `ASL Imager`

The `ASL Editor` is a part of the `ASL for Windows` software project intended for VLBI data editing and visualization. With the ASL Editor, you can :

- view the observation data written in FITS format and their parameters
- edit the data (both time and spatial editing)
- get statistical and other parameters of the data
- prepare the data for VLBI image synthesis

`ASL Editor` includes FITS-UVX Viewer/Converter to view an input FITS file and then to convert it into UVX format (internal ASL format) for further processing. ASL Editor also has a FITS Writer to convert a UVX file back into FITS format

The `ASL Calibrator` consists of two independent parts :

- amplitude calibration
- fringe-fitting

The ASL amplitude calibration procedure uses some additional data to estimate the amplitude of each antenna gain coefficient as a function of time and frequency band (IF). Three kinds of additional data are acceptable :

- calibration text file
- calibration tables (GC and TY)
- if one of the observed sources has a stable flux and is unresolved, then it can be used as a calibrator

After the amplitude calibration procedure is completed, we have a new UVX-file which contains the calibrated visibility values (in Jy).

The `ASL Fringe Fitting` procedure is the first stage of the data phase calibration. With the ASL Fringe Fitting you can :

- fix phase errors on the correlator output
- compensate visibility phases for baseline-movement during the observation

The procedure consists of the following steps :

- dividing the total observation time interval into a few equal parts (solution intervals)
- executing the `"Fringe Search"` procedure to find an initial approximation for four parameters (amplitude, delay, fringe rate, initial phase) for each solution interval
- correcting the data phase by means of a non-linear Least Mean Square Method for each solution interval
- storing each corrected visibility function into an output UVX file

Two possible options for Fringe Fitting can be executed:

- single-band Fringe Fitting (separately for each Intermediate Frequency (IF) band)
- multi-band Fringe Fitting (for all available IF's)

The `ASL Imager` is a part of the `ASL for Windows` software project intended for VLBI image synthesis and visualization. With the `ASL Imager`, you can :

- synthesise various kinds of VLBI maps
- analyze the images obtained
- deconvolve images by means of `CLEAN`, or advanced `Self-Calibration` procedures

`CLEAN` belongs to the class of methods inverting the convolution operation. More concretely, it approximates the unknown source brightness distribution distorted by a complicated beam associated with poorly sampled `(u, v)-plane`. In `ASL for Windows`, the cleaning procedure combines interactive graphical selection of a region to be cleaned with continuous graphical control of the algorithm, with a possibility to let the procedure proceed in automated batch mode. The user can continue other work with ASL as `CLEAN` is running. Moreover, the user can change the loop gain, and control the stopping criteria by setting the threshold, maximum number of iterations, or directly stopping the procedure upon reaching a visually acceptable result. `CLEAN` is included into the `Self-Calibration` procedure and can be called and used at any iteration of `Self-Calibration`

ASL Imager includes many graphics features which allow you to obtain the best results in the shortest time.

ASL software uses the following general scheme of VLBI data processing :

- Transformation of FITS-format data into simplified internal UVX-format
- Amplitude Calibration of the UVX-data obtained using available calibration data
- Fringe Fitting procedure and primary calibration of the phase of the visibility function
- Editing of UVX-data obtained
- Reconstruction of a radio image of the source
- Analysis of the reconstructed image
- Transformation of the UVX-format data back into a standard FITS-format if necessary

Thus, the ASL software carries out a certain cycle of VLBI data processing. The goals of such data processing are to make conclusions concerning the quality of the VLBI and calibration data available and to reconstruct the image of the source if data quality is reliable. The ASL software uses high-class user-friendly development tools at all stages of data processing. The main features of such tools are :

- the ability to compare the data before and after any stage of processing
- the capability of visual control of the Fringe Fitting procedure
- the capability of visual control of the image reconstruction during the `CLEAN` and `Self-Calibration` processing

• the feasibility to interrupt the current process and to repeat it with other input parameters at any stage of VLBI data processing

The ASL software uses some sophisticated mathematical methods to solve appropriate problems. For instance, a regularization method or a modern method of optimization can be used to reconstruct the image from VLBI-data with poor `(u, v)-plane` coverage (see Likhachev et al., 1998).

4. Demonstration of ASL data processing

To demonstrate the ASL software capabilities, we can use VLBA-data of the 6 cm VSOP pre-launch survey. These data were kindly placed into our disposal by Dr. Edward B. Fomalont (NRAO). VLBA-data for the source 1230+122 (Vir A) are used for such demonstrations. The initial data volume is about 6 MByte and the total observation time interval is 2.5 min; the quality of these data is fine. Thus, such data seem to be very suitable for a quick demonstration of ASL data processing.

5. Conclusions

The main goal for creating and developing `Astro Space Locator (ASL for Windows)` software is to give another possibility for VLBI data processing to astronomers who prefer to deal with PC-computers. It seems to be more compatible to install the ASL software in PC computers than to use a UNIX/LINUX computer to install other software for VLBI data processing. The ASL software uses the standard Windows System and standard IBM PC computers, which are more affordable. Moreover, any user can install the ASL software himself. It is not necessary, to be a Windows System specialist to make any necessary operations. The ASL software can be quickly and easily installed and used at antenna sites or in a home environment. To make setup of the current version of ASL software, you have to obtain a ZIP-file of a few MB size, unpack it and execute setup. The ASL software is free and available on the Internet (see `http://platon.asc.rssi.ru/DPD/ASL/asl.html`).

Development of `ASL for Windows` is continuing and our future plans include the creation of software modules for `Multi Frequency Synthesis` data processing. Moreover, we intend to try to unify the Fringe Fitting and Self-Calibration procedure. Such a software module should to be very useful for `Space VLBI` data processing.

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